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September 2007

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Engeman, Richard M.; Constantin, Bernice U.; Shwiff, Stephanie A.; Smith, Henry T.; Woolard, John; Allen, John; and Dunlap, John, "Adaptive and economic management methods for feral hog control in Florida" (2007). *USDA National Wildlife Research Center - Staff Publications*. 691.  
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# Adaptive and economic management methods for feral hog control in Florida

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## Abstract:

Feral hogs (*Sus scrofa*) negatively impact the environment in most places around the world where they have been introduced into the wild. In many places, hog removal is essential to protect special habitats, in particular, wetlands. This paper describes techniques developed for use in adaptive management approaches to enhance hog removal efforts in Florida, as well as methods to evaluate the economic impacts from hog management. A valuable adaptive management tool that can be an easily applied index to monitor feral hog activity is track plots. This method has been effective for monitoring hog distribution and relative abundance, thus aiding the location and timing of control method applications and the evaluation of control results. Hogs are usually managed because they are causing damage. Hence, it is also essential to monitor damage before and after implementation of a control program. To accomplish this, we developed a quadrat sampling methodology to estimate the percentage of hog-damaged habitat. We applied quadrat sampling safely to fragile seepage slopes. We also employed a series of transects specially applied to efficiently estimate damage to riparian zones. Hog management, like all wildlife management, is also rooted in economic realities. Hence, we developed means for estimating the monetary value of the damage based on the dollar amounts that wetland regulators have charged permit applicants to mitigate their damage to wetland resources. Universally, the economic analyses have demonstrated enormous benefit-cost ratios for hog removal.

**Key words:** damage assessment, economic analysis, economic valuation, feral hogs, human–wildlife conflicts, invasive species, population indexing, *Sus scrofa*

**FERAL HOGS** (*Sus scrofa*) are a particularly destructive exotic species in many areas throughout the world (Seward et al. 2004, Adkins and Harveson 2007, Mersinger and Silvy 2007). They negatively impact the environment through habitat degradation, predation on native species, and competition with native fauna (Choquenot et al. 1996, Taft 1999). Hogs possess the highest reproductive potential of any large mammal in North America (Wood and Barrett 1979, Hellgren 1999), and the species currently inhabits many areas in such large numbers that they adversely impact the environment and surrounding agriculture (Rollins et al. 2007). In Florida, feral hogs are a major agricultural problem, with >500,000 of them inhabiting the

state (Layne 1997). Feral hogs also can harbor diseases transmittable to livestock and humans (Conover and Vail 2007, Hartin et al. 2007). In particular, the hog industry in the United States has nearly eradicated swine brucellosis and pseudorabies, but feral hogs serve as a potential reservoir from which these diseases can be transmitted to domestic livestock (Hartin et al. 2007).

In Florida, large proportions of unique natural environments have been lost to urban development and agriculture. Much of what little remains is currently threatened by feral hogs. The USDA/APHIS/Wildlife Services (USDA/WS), the federal agency mandated to resolve human–wildlife conflicts, has been act-

ively protecting these increasingly rare and fragile natural habitats by removing the feral hogs inhabiting them. Here we describe a valuable adaptive management approach to feral hogs and field methods that we developed for feral hog removal. Our approach is based on (1) monitoring changes in hog densities, (2) assessing the level of damage caused to the environment before and after hogs have been removed, and (3) determining if the removal program has been cost-effective based on the prevention of ecological damage. We also managed hog removal from an economic perspective using procedures to economically assess hog damage.

## Methods

We developed several practical field methods to facilitate adaptive management of feral hog populations. These methods provide the information required to remove hogs effectively and efficiently, including the detection, relative abundance, and distribution of hogs, as well as methods to assess damage levels. Hog management, like all wildlife management, has to be cost-effective. Thus, we also developed methods to assess the monetary value of the environmental damage caused by feral hogs.

### Determining a population index

Logistical and theoretical difficulties are associated with density estimation methods (see Liedloff 2000 for an excellent overview of potential problems with mark-recapture methods). We found that indices of abundance were the only practical means for monitoring hogs, rather than absolute abundance estimates (see Choquenot et al. 1996), due to the difficulty of actually measuring feral hog density (Liedloff 2000). For our purposes, a passive tracking index (PTI) has been an efficient means to monitor feral hogs (Engeman et al. 2001). Collection of these data has been vital for adapting and optimizing management strategies to achieve maximal impact on hog populations with the resources available.

The PTI originated for monitoring wild canids in Australia (Allen et al. 1996) and subsequently proved effective for hogs (Engeman et al. 2001). This low-tech method involves placement of tracking plots throughout the area of interest in hog travel routes, such as dirt roads or tracks. At each plot, the number of hog track sets (number

of intrusions into the plot) is recorded for 2 consecutive days at each assessment time. After 24 hours, the plots are examined for spoor and resurfaced (tracks erased and surface smoothed) for the next day's observations. The PTIs and associated variances are calculated according to methods developed by Engeman (2005) where a mixed linear model (e.g., McLean et al. 1991; Wolfinger et al. 1991) describes the number of intrusions on each plot each day. Adding to the robustness of the index, the variance formula derivation was based on a nonzero covariance structure among plots and among days, that is, without assumptions of independence among plots or days (Engeman 2005).

Maintaining permanent passive tracking plot locations maximizes index comparability over time (Ryan and Heywood, 2003), providing a useful means to assess the changes in feral hog abundance while simultaneously providing information to describe the spatial distribution of their activity. For most properties, we created tracking plots 3-m long that spanned the dirt road or track (Engeman et al. 2001). However, for Eglin Air Force Base, an extraordinarily expansive property, we dragged chains behind a pickup truck to prepare plots 1.6-km long (Engeman et al. 2007a). While the same index calculations are applicable to data from both plot designs, the resulting index values should be considered different statistics not directly comparable due to different dimensions of the tracking plots (Engeman 2005). Applications of the tracking plot information and the PTI have included (1) optimizing the timing and strategy for hog removal, (2) minimizing labor by identifying areas where hog removal would have maximal effect, (3) assessing efficacy of removal efforts, and (4) serving as a detection method for reinvasion and identification of directions from which reinvasion occurs.

### Assessing damage to natural habitats

The primary management objective behind our hog removal efforts has been to reduce damage to natural habitats. Therefore, we developed practical damage assessment methods to assess the need for and success of hog management efforts. Due to variability among habitats and associated difficulty in traversing the terrain, our sampling methods had to be adaptable to different circumstances. We applied quadrat



Bernice U. Constantin prepares a tracking plot used for indexing hog populations.

and line-intercept methods for sampling hog damage to natural environments. We identified hog damage as ground overturned during foraging (rooting) activity. Armadillos (*Dasypus novemcinctus*) are the only other species in Florida that could produce superficially similar (small) patches of damage. We easily distinguished hog damage from armadillo damage by examining the tracks they made and by determining whether the ground was overturned by rooting hogs or dug by armadillo forefeet.

**Quadrat sampling.** A quadrat sampling method was developed for use in conjunction with the PTI plot locations for estimating habitat damage by hogs (Engeman et al. 2003). Each tracking plot location defined the location for 2 damage assessment plots. On 1 end of the tracking plot, we created a damage plot 1 m perpendicularly away from the tracking plot's edge. Each damage plot was a 5- x 1-m rectangle, with the long dimension paralleling the road and 1 m outward from it. Each 5- x 1-m plot was established using a 1- x 1-m square constructed of PVC pipe. This square was folded over 4 more times beyond its initial placement to establish the plot. We cryptically placed sand-colored, wooden stakes in diagonal corners to define the plot for future reference. We placed string in a plus sign (+) across the 1- x 1-m square to divide the area into 4 equal quadrants. The second damage plot defined at the same road location was constructed in the same manner on the opposite side of the road beginning 3 m in the opposite direction and leading away from the first damage plot. We could measure damage over 20 of these 0.25 m<sup>2</sup> quadrants for each of the 5- x 1-m plots. Damage was estimated as the mean

percentage of area of damage across the plots.

Seepage slopes were also sampled for hog damage using 1- x 1-m square quadrats, although the quadrat placement was considerably different. Rather than being able to associate quadrat location with tracking plot location, the isolated and confined nature of seepage slopes were best sampled by randomly placing the 1- x 1-m quadrats throughout the seepage slope, with the same plot coordinates maintained over years (Engeman et al. 2007a).

**Line intercept sampling.** We also employed a line intercept sampling scheme to effectively assess damage to the last remnant of a once-extensive basin marsh system in Florida (Engeman et al. 2004b). We spaced tape measure transects through the area from the water's edge to the interface between the marsh and the surrounding community of upland vegetation (Engeman et al. 2004b). We measured the total distance of each transect, as well as the distance directly on the transect that was damaged by hogs. This amount could represent a single patch of habitat or the combined distances of multiple patches. Damage was estimated as the proportion of the mean transect that overlay areas damaged by feral hogs. The same approach has also been designed (but not yet used) to estimate damage by a burgeoning feral hog population along stream drainages in southeastern Colorado and could be applied to many riparian situations.

## Economic valuations

Determination of monetary values for protected habitats was neither a straightforward nor a precise process. A means of applying a monetary value on a unit-area basis to damaged native habitats was needed to estimate the unit (per ha) and total cost of hog damage. Analogies to methodologies used for valuing threatened and endangered species were considered for application to habitat values (Engeman et al. 2004a). One simplistic consideration for valuation of habitat was to appraise the land on the basis of market value. However, special habitats such as wetlands have limited market value, and if such habitat is selectively protected, the market value diminishes further (King 1998). The use of contingent valuation surveys to place a value on special habitats tends to be abstract appraisals of value (King 1998), and they are rarely used for policy decisions (Adamowicz 2004). Estimated



costs for restoring habitat to pristine condition (replacement costs) frequently produce values well in excess of the public's willingness to pay, and therefore also do not represent a realistic valuation.

The most defensible, logical, and applicable valuation for the damaged habitats targeted for hog management was expenditure data for permitted wetland mitigation projects in the United States. Such data represent an empirical demonstration of willingness-to-pay value. King (1998) presented the dollar amounts/unit-area spent in efforts to restore a spectrum of wetland habitat types. The numbers represent the dollar amounts that environmental regulators, and, to a degree, elected governments have required permit applicants to spend to replace a damaged wetland's services and values (King 1998). We identified the dollar value for the appropriate wetland habitat category from each of the 2 studies cited in King (1998) for application to each habitat type under study (Engeman et al. 2003, 2004b).

### Economic analyses

Estimating the amount and the associated value of hog damage allows for the application of benefit-cost analyses in order to evaluate the need and success of hog control from an economic perspective, or to compare the economics of hog management approaches. The benefit-cost model approach to hog management involves estimating the monetary value of the benefits measured in per-ha damage saved versus the costs measured in per-ha damage lost plus control costs. The objective of minimizing opportunity costs is equivalent to maximizing net benefits (Boardman et al. 1996). Benefit-cost ratios (BCRs) were calculated using the standard format of the ratio of benefits to costs (Loomis and Walsh 1997, Boardman et al. 1996, Nas 1996, Zerbe and Dively 1994, and Loomis 1993). If a  $BCR > 1$ , then the rewards for hog removal exceeds the costs, whereas a  $BCR < 1$  would suggest that hog removal conducted in that fashion is not economically efficient.

When comparing management approaches, the benefits of one approach are represented as the opportunity cost of pursuing an alternate approach. Measured this way, the benefits of following approach 1 in lieu of approach 2 are represented by per-ha value of damage saved

by not pursuing approach 2. This implies that the benefits of approach 1 in comparison to those of approach 2 are represented by the opportunity costs of pursuing approach 1. Or, seen in another way, the benefits that accrue to each approach will be measured in terms of the cost saving as compared to alternate approaches. The BCRs must be evaluated in terms of the other approaches available. The benefits accruing to approach 1 depend on the value of per-ha habitat lost in the alternate approaches not followed. For example, the benefits accruing under approach 1 in comparison to approach 2 are measured by the following equation:

$$BCR_{1,2} = K = \frac{\text{per-ha damage value saved by not following approach 2}}{\text{per-ha damage value for following approach 1}}$$

That is, the benefit in terms of damage amount of approach 1 (in lieu of approach 2) is K times greater than the cost of approach 2. For an approach to be considered feasible it should be the case that  $K > 1$ . If  $K < 1$ , then pursuing that approach is less cost-effective than the approach that is not being used.

### Characteristic results

We have employed adaptive and economic management of many feral hog populations in Florida through application of our field methodologies, culminating in economic valuations and analyses. Our results from many hog control projects have universally demonstrated extraordinary economic benefits relative to the costs of control. For example, in Jonathan Dickinson State Park in southeast Florida, damage to wet pine flatwood habitat (Florida Natural Areas Inventory [FNAI] 1990) was only 1%, but the value of that damage level to only 1 ha exceeded the costs for control applied to the entire park (Engeman et al. 2003). In nearby Savannas Preserve State Park, during only the first year of control in the vicinity of the remnant basin marsh mentioned earlier, damage was reduced from 19% to 7%. That reduction in lost habitat was valued between \$1 million and \$3 million, and the corresponding benefit-cost ratios showed control to be 134 to 436 times greater in its value than its costs (Engeman et al. 2007b, 2004b). On Eglin Air Force Base, which covers a large area of wildlands in Florida's panhandle, recreational

hunting was shown to have a beneficial effect on hog damage levels to imperiled seepage slope habitat, with seepage slopes in areas open to hunting having 11% damage versus damage in 25% of unhunted areas. However, less than a year after instituting hog removal in only the unhunted areas, damage there was reduced to 7%. Moreover, there was an additional carryover effect to the hunted (uncontrolled) areas whereby damage dropped to 6%, making damage levels in the controlled (unhunted) and uncontrolled (hunted) areas statistically indistinguishable. The resulting benefit-cost ratio for control was 55 to 1 (Engeman et al. 2007a).

### Discussion

Each area of field method development has proven valuable for adaptive management of feral hogs. Each method has contributed substantially to the efficacy of hog removal efforts. The PTI is an effective tool for planning and assessing hog removal efforts, as well as for follow-up monitoring to determine if and where additional control is needed. Protection and improvement of habitats have been the ultimate goals of our hog removal efforts. Therefore, reliable and practical means to estimate damage levels provide true evaluations of the need and efficacy of hog control. The ability to value the habitat resource provides an effective economic management tool for evaluating conservation approaches. Economic analyses can greatly assist managers to allocate limited funds towards habitat conservation most efficiently and effectively. Ultimately, many conservation funding decisions are made on a political level by people without high levels of training or expertise in biological sciences. While it is essential to obtain high-quality data to understand the biological impacts of management efforts, placing conservation issues in an economic context can greatly enlighten the political decision-making process on hog removal.

### Acknowledgments

We thank M. Conover for his valuable suggestions on the direction of this paper.

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**JOHN WOOLARD** is a wildlife specialist for USDA/APHIS/Wildlife Services. He is noted for developing animal control technologies, including sturdy portable pen traps for hogs and bait stations for invasive rodents that exclude native species. He has participated in many groundbreaking research studies in such areas as protecting sea turtle nests from predation and protecting rare habitats from feral hog damage. He also is a licensed alligator trapper and oversees the removal of many nuisance and potentially dangerous alligators each year.



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